# Can bomb radiocarbon be used to estimate anthropogenic carbon dioxide inventories?

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It has been suggested that oceanic bomb radiocarbon provides a less than ideal means for estimating oceanic anthropogenic carbon dioxide content, because modeled column inventories of bomb radiocarbon do not correlate well with modeled column inventories of anthropogenic carbon dioxide (e.g., Heimann and Maier-Reimer, 1996). This poor correlation is primarily due to the different time-histories of the radiocarbon and anthropogenic $CO_2$ forcings, and only secondarily due to other factors such as biological transport of carbon isotope perturbations and small differences in air-sea gas transfer.

In the deep ocean, where bomb radiocarbon concentrations are small, one would expect a relatively high ratio of anthropogenic $CO_2$ to bomb radiocarbon. This is because anthropogenic $CO_2$ has had more time to penetrate to the deep ocean than has bomb radiocarbon. In the surface ocean at the time of GEOSECS, one would expect to see a relatively low ratio of anthropogenic $CO_2$ to bomb radiocarbon. This is because there was a large pulse of radiocarbon to the atmosphere in the 1960's. These considerations suggest that there may be a non-linear relationship between bomb radiocarbon and anthropogenic carbon dioxide concentrations in the ocean.

We have performed simulations of the ocean carbon chemistry with LLNL's version of the Bryan-Cox model. We have estimated biological productivity with a Najjar-style restoring to surface phosphate concentrations. Organic carbon productivity is partitioned into DOM and POM. Silica productivity is estimate by restoration to surface silica concentrations. $CaCO_3$ productivity dominates in areas in which surface silica is largely depleted.

Based on this model, we determined that anthropogenic $CO_2$ concentrations can be estimated using a quadratic regression on $\Delta^{14}C$. The best fit equation for 1975 (based on a grid-cell by grid-cell regression which tends to overemphasize the surface ocean and high latitudes) for anthropogenic $CO_2$ ($\Delta[\Sigma CO_2]$ in $\mu M/l$) as a function of the change in radiocarbon $\Delta^{14}C$ value ($\Delta\Delta^{14}C$ in ‰), with a 2-sigma error of 6.9 $\mu M$, is:

$$\Delta[\Sigma CO_2] = 3.34 + 0.275\ \Delta\Delta^{14}C - 6.05 \times 10^{-4}\ (\Delta\Delta^{14}C)^2.$$

The corresponding regression for $\Delta[\Sigma CO_2]$ as a function of the change in $\delta^{13}C$ ($\Delta\delta^{13}C$ in ‰) in 1975, with a 2-sigma error of 5.6 $\mu M$, is:

$$\Delta[\Sigma CO_2] = -0.39 - 92.5\ \Delta\delta^{13}C - 54.8\ (\Delta\delta^{13}C)^2.$$

The $\delta^{13}C$ regression tends to work better than the $\Delta^{14}C$ regression in the deep ocean where bomb radiocarbon values are small. Also, the $\delta^{13}C$ regression is likely to be more stable with time than the $\Delta^{14}C$ regression.

This general approach may be useful way to estimate anthropogenic $CO_2$ inventories from tracers such as CFCs that have had emission histories that differ from that of anthropogenic $CO_2$. Limitations of this approach and geographical variability in the above relations will be discussed.

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